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(Academy of Medical Sciences USSR)

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PROBLEMS IN EVALUATING THE PHYSICAL FITNESS OF COSMONAUTS (Based on Materials of the Voskhod-1 and 2 Flights) */1

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The physical fitness of astronauts under conditions of weightlessness and space environment was tested in orbital flight (Voskhod-1 and 2), including visual efficiency, postural-tonic reflexes, adaptation, reaction time to stimulus, and time required to perform assigned tasks. With increase in time spent in space, the reaction times returned, from an initial rise, to ground-level values. The resolving power of the visual analysor showed no major changes, while the visual working capability declined slightly toward the end of the flight. Operative memory (skill test) and reliability margins decreased in time, with the mean-square error in orbital flight being greater than in simulators on the ground. Absence of reference points is believed to greatly affect motor coordination in walks outside the capsule, unless using cables as support lines.

The control of an orbital spacecraft today has been thoroughly automated, and the astronaut intervenes in the control process only on certain sectors of the flight. However, the progressive development in space research makes it imperative to widen the scope of the astronaut's duties and upgrade his role. Data on the physical fitness of the astronaut, the possibility of his performing

* Numbers in the margin indicate pagination in the original foreign text.

the assigned program of operation, research work, and manipulations involved in the control of the ship, thus become particularly important.

Extensive laboratory studies on the characteristics of the activity and physical fitness of the astronaut - studies that more or less simulate the factors of space flight - permit formation of a definite opinion as to the possible tasks that can be assigned to a human being in space flight. The above studies, which are merely for general guidance, require more exact estimates of the physical fitness of human subjects under the conditions of space flight. This requires a series of investigations under the conditions of actual flight.

At the present stage of the development of space technology, the technical possibilities and the desires of scientists studying the physical fitness of the astronaut must of necessity be compromises, in view of the size and extent of the research equipment. However, in the USSR such studies are made on manned spacecraft in orbit. This general trend has been specifically emphasized in /2 the last two flights of spacecraft of the "Voskhod" type.

To study the physical fitness of a human operator under the influence of space flight environment, the following methods were used:

time study of the operations;

study of the resolving power of the visual analysor (visual efficiency);

study of the visual operative fitness;

estimation of the features of analysis and the quality of the operative memory in working with contours of regular and random lines;

study of the dynamic characteristics of human subjects included in the control system of a simulation system with immediate and delayed feedback.

In addition, the biomechanical analysis of the nature and peculiarities of motion of A.Leonov during his walk outside the capsule, and the results of his work under these conditions, were of immense interest.

It is generally known that coordinated motion is the foundation of any purposeful activity. However, the coordination of motions is affected both by the changed mechanical conditions (weightlessness and conservation of mass and thus

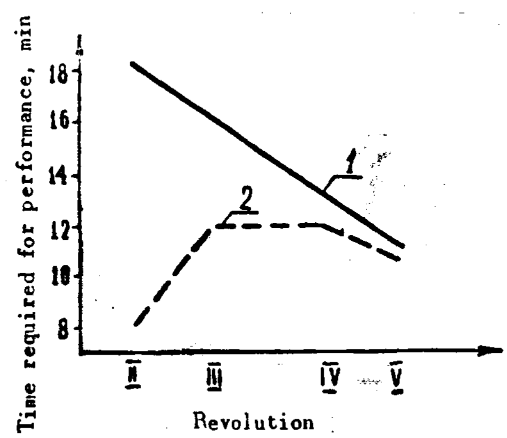

Fig.1 Time Required by V.Komarov to Perform Manual Control of the Craft, under Various Conditions
1 - In space; 2 - In training at UKK

also of inertia) and of afferentation, changing the direction of motion by the feedback principle. Under conditions of weightlessness, the setting and postural-tonic reflexes, which are the foundation of all other motor coordinations, are completely changed. Further than that, in free space, the absence of reference points creates completely new conditions of support-free space, which are unusual for biomechanics.

The results of studies under brief periods of weightlessness and under the effect of acceleration have proved the excellent compensatory capability of the human body in coordinating elementary motor acts (Bibl.2, 3, 5, 7, 8). Also the handwriting of the astronauts improved appreciably from revolution to revolution (Bibl.1, 4, 6). The ability to perform complex tasks, which are under the control of the cerebral cortex and the mechanisms of adaptation, should be more favorable.

In fact, the astronauts of the "Voskhod-1" and "Voskhod-2" encountered no particular difficulty in performing the manipulations assigned to them according to the program. However, a time study of a series of operations (work in controlling the craft, medical procedures, and checks, etc.) as well as logic tests showed that, at the beginning of the flight, the time required was somewhat longer than that of ground standards or the time needed by the astronaut to perform the same manipulations at later stages of the flight.

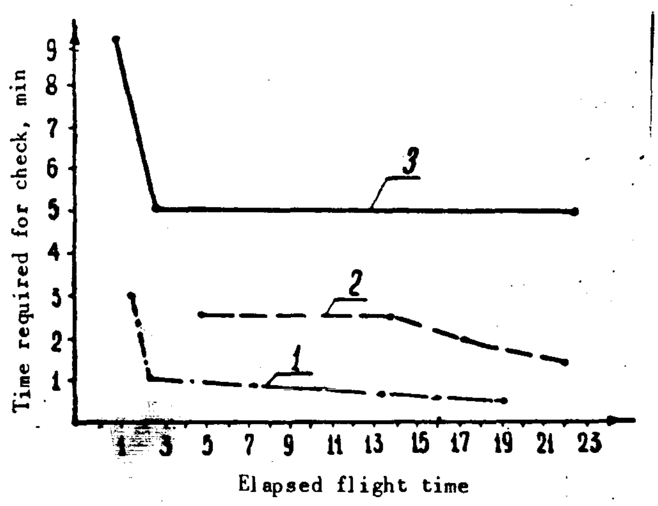

Fig.2 Time Required by B.Yegorov for Medical Checktests at Various Stages of the Flight:
1 - Blood analysis; 2 - Vestibular test;
3 - Blood pressure tests

For example, on the second revolution, V.Komarov took about twice as long for the motions connected with orientation of the capsule as he did on subsequent revolutions or on the ground (Fig.1). /3 The same was also noted by B.Yegorov in performing almost all the medical checktests (Fig.2). Most likely this can be explained by the effect of "external inhibition" resulting from the novelty of environment, as well as by the transition of the organism from the state of acceleration to weightlessness. In the subsequent phase of the flight these phenomena, as a rule, are smoothed out and compensated. This definitely would not happen if the crew were pretrained on orbiting space stations. /4

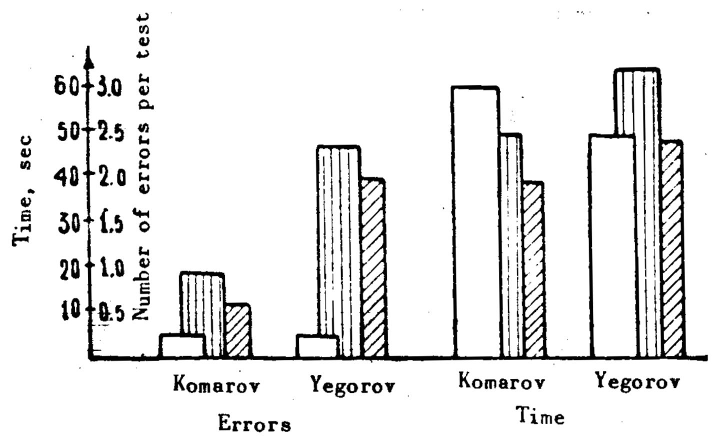

Fig.3 Dynamics of Visual Operative Fitness of Yegorov and Komarov

A study of the resolving power of the visual analysor (allowing for the nonstandard illumination conditions) showed no appreciable changes. The operative visual fitness in a number of cases, especially toward the end of the flight, showed a slight decline (Fig.3).

In studying the features of the analysis and quality of the operative memory, errors of constant number were noted. However, during the first revolutions the astronauts committed errors only in the more intricate parts of the contours constructed on the random principle whereas they also committed errors in the standard part toward the end of the flight. On the whole, the errors were attributable to disturbances of reproduction, i.e., to a weakening of the operative memory.

The study of the dynamic characteristics of the operator in a simulated control system was very interesting. The input signals used were graduated, of random type, and were sinusoidal signals with nonmultiple frequency characteristics*. The operator was able to accomplish control with immediate and delayed feedback in the system. The results show that, in actual space flight as compared with data obtained in simulators of the capsule and in training, the mean-square error of the operator increases (up to 25%), showing a steeper rise at higher frequencies of the signal (Fig.4). The reliability margins of the operator under the influence of space flight factors likewise decline with respect to the phase and the modulus of the amplitude-frequency characteristics. These data might be highly useful in designing new control systems. /5

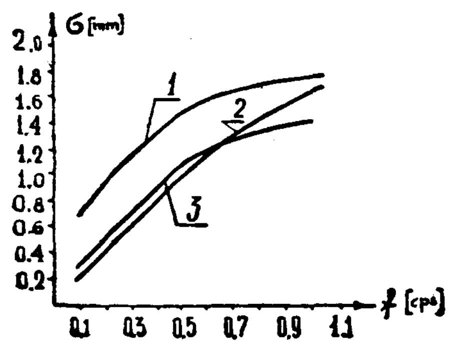

Fig.4 Work Characteristic of Astronaut P.Belyayev
on a Control System Simulator
1 - Flight; 2 - Training; 3 - Day of lift-off

Thus, the cumulative data indicate in-flight maintenance of an adequate level of physical fitness, ensuring satisfactory performance of the flight program. The disturbances noted during the orbital flight tests will be used as a basis for corrective proposals and measures.

The results of A.Leonov's walk in space are important to define the possibility of performing various operations by locomotion in space and in the assembling of orbital platforms. Under these conditions, weightlessness enters a new stage of research, namely, the phenomenon of referenceless space. The

* V.K.Filosofov participated in the analysis of the material presented on the study of the dynamic characteristics of human subjects.

smallest effort will result in rotating the body in various planes at a rather high angular velocity, thereby intensifying the vestibular stimuli and disorganizing purposive action. Motion pictures taken of the astronaut, on leaving the capsule, confirmed this proposition.

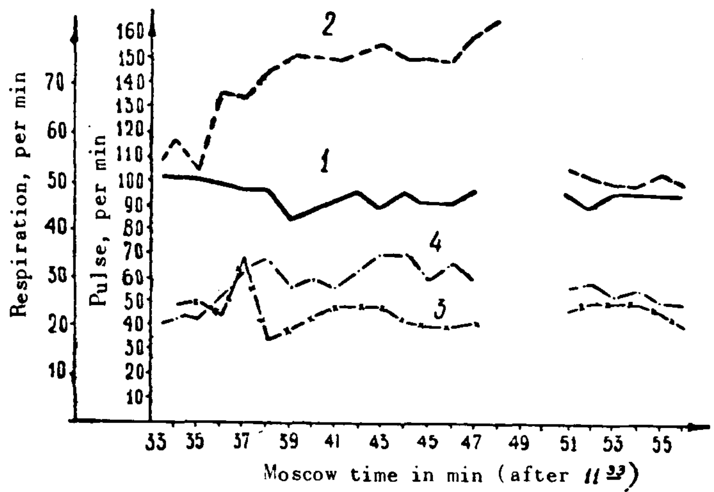

Fig.5 Dynamics of Pulse and Respiration of the Crew of the Space Ship "Voskhod-2" during Space Walk of A.Leonov
1 and 3 - Respiratory rate for Belyayev;
2 and 4 - Same for Leonov

A preliminary biomechanical analysis of the nature and features of the movements of Leonov in his locomotion outside the capsule (as under ground conditions on a special stand stimulating unsupporting space) indicate entirely satisfactory motor coordination and the possibility of performing purposive displacement and volitional actions,provided cables are used as points of support. Thus, Leonov required only eight training periods to move without faltering on a supportless stand simulating the flight mission.

In his actual walk in space, the astronaut performed all assigned movements, applied the tourniquet, took up the life line, etc. He was also able to perform the required manipulations to set the motion picture camera and to disassemble it before returning to the capsule. All operations were performed man- /6 ually with no difficulty whatever. This proof is indirect but is convincingly illustrated by the dynamic frequency of the pulse (Fig.5). At the time of leaving the capsule and during his stay in space, some acceleration in pulse and respiration was noted in Leonov, which naturally could be attributed to emotional stress. After return to the craft, both rapidly returned to normal. Thus, at the end of his stay in the air-lock, his pulse was 100 - 120, corresponding to the rate during similar training on the ground. At the instant of entering outside space, the rate increased to 150 - 160. On re-entering the air-lock, when the astronaut had to overcome certain difficulties, the pulse rose to 168, but within the lock itself, the rate declined relatively rapidly to 100 - 120.

The data obtained in investigating the factors of physical fitness of astronauts in orbital flight show that the changes noted are quite specific and are due to the influence of a group of certain space environment factors. Such data are of considerable interest in designing control systems, in planning research programs, and in laying out working conditions for astronauts in space.

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